INTEGRATED OPTICAL LIGHTGUIDE DEVICE

This application is a continuation of International Application No. PCT/NL99/00222, filed April 16, 1999, which claims priority of Netherlands Patent Application No. 1008934, filed April 20, 1998.

The invention relates to an integrated optical lightguide device comprising a light-transmitting layer and inclusion layers and being provided with an activable element.

A device of this kind is known from the article "Fabrication and packaging of integrated chemico-optical sensors" by R.G. Heideman et al., published in Sensors and Actuators B 35-36, 1996, pp. 234-240. Besides sensors and actuators in a general sense, said article describes in particular a Mach-Zehnder interferometer comprising a sensor film, which is for example sensitive to air humidity. Said article furthermore describes an embodiment wherein an optical fibre for light supply is integrated in the Mach-Zehnder sensor.

Generally, such a device is much too complicated for practical applications and thus relatively costly, and in some cases it is sensitive to interference signals or to small deviations between intended and realised local refractive index profiles.

The operation of known integrated optical sensors and actuators, such as the Mach-Zehnder interferometer, is usually based on a phase change of the light being used, which is induced by the activating quantity, which imposes restrictions as regards the light sources to be used for that purpose. For the lightguide structures to be used this means furthermore that any transitions in the optical structure, among which also the transitions to and from the activable element which takes care of the intended actuator or sensor operation, will have to be provided very gradually in the direction of the light propagation, as a result of which they will be

relatively long.

The object of the invention is to obviate the above drawbacks, and in order to accomplish that objective an integrated optical lightguide device of the kind mentioned in the introduction is characterized in that said activable element is divided in a light propagation direction of the lightguide into several, mutually separated individual segments having different refractive index profiles and/or different material profiles. Said segmentation may relate to a slab-type lightguide as well as to a channel-type lightguide. This optical lightguide device can for example be used as a sensor, as an intensity modulator and as a spectrophotometer.

The invention is essentially based on the insight that when a guided light beam passes through a boundary surface between two light-transmitting parts having mutually different refractive index profiles, the portion of the light that is transmitted by said boundary surface as a beam guided within the light-transmitting structure is determined by the difference in the refractive index profile between said two light-transmitting parts. Especially the degree of light reflection resulting from said difference in the refractive index profiles and the degree to which the light exits the lightguide in the form of radiating modes as a result of a mismatch of the guided mode field profiles of the light being used on either side of said boundary surface are the determining factors in this case. When a change in the value of an external physical or chemical quantity directly or indirectly causes the refractive index profiles of the lightguides on either side of the boundary surface change to change to different degrees, the consequent changes in the effective refractive indices and the mode field profiles

will produce a change in the amounts of light reflected on the boundary surface, in the light beams transmitted by the boundary surface as guided modes as well as in the light beams emitted on the boundary surface in the form of radiating modes. Thus, the (change in the) amount of light transmitted as a guided light beam is determined by and constitutes a measure of the (change in the) external quantity. Instead of the light transmission, also the amount or the distribution of the light converted into radiating modes and/or the amount of reflected light may function as a measure of the (change in the) external quantity. Essential in this respect is the fact that the intended effect does not depend on the degree of coherence of the light being used, and consequently it is also possible to use inexpensive, non-coherent light sources, such as light-emitting diodes (LEDs), fluorescent lamps, halogen lamps, Xenon lamps etc. as a light source besides relatively expensive gas lasers, solid matter lasers and/or laser diodes.

Although the changes may be relatively small in the case of a single transition, the use of many transitions succeeding each another in the direction of the light propagation may produce significant effects. Essential in this respect is that the degree of repetition of said transitions, and thus of the segments of the activable element, does not need to be periodical, because the operating principle is not based on phase information of the light being used, although it is also quite possible for a device according to the invention to use periodically repeated segments.

In one preferred embodiment, the device comprises, in succession, a carrier, a first inclusion layer, a light-transmitting layer and a second inclusion layer. If suitable specifications are used, in particular as

regards the refractive index, said carrier can also function as a first inclusion layer.

The forming of such layer structures can be done with well-defined, controllable techniques which are known per se. Thus, layers having a precisely defined thickness and composition can be realised by means of vaporisation, CVD techniques and the like. In one preferred embodiment, channel-type lightguides are formed in said layer structures by means of e.g. photolithographic techniques and etching techniques. In a device according to the invention, the activable element is built up of segments of at least two different kinds. Segments belong to the same type if they exhibit similar refractive index profiles and material profiles in a plane perpendicularly to the propagation direction of the lightguide. Accordingly, segments of the same type exhibit the same degree of activability, that is, the effective refractive indices and the mode field profiles of the guided modes in segments of the same type are influenced to the same degree by the quantity to which the activable segment is sensitive. The dimensions of segments, measured in the propagation direction of the lightguide, range between approx. 1 micron and a few dozen micron.

Activable segments contain an activable material, which in this case means a material whose refractive index value depends on the quantity of an external quantity. These materials include for example chemico-optical transduction materials, whose refractive index depends on the concentration of a specific substance or of several substances. Besides the above materials, also thermo-optical, electro-optical, magneto-optical, opto-optical and elasto-optical materials can be used, which can be activated by, respectively, a temperature change, an electric field, a magnetic field, a light intensity

and a mechanical stress or stretch.

In one preferred embodiment, said activable element consists of a succession of two types of segments, wherein each type exhibits a different degree of activability.

In another preferred embodiment, the activable element consists of a succession of two types of segments, with the activability of one of said types being zero. In this case, the activable segments are monotype activable segments, which are mutually separated by segments which are insensitive to the quantity, the so-called bridge portions.

In another preferred embodiment, segments exhibiting different degrees of activability are formed by:

- the local removal of (part of) the light sealing layer covering the light-transmitting layer, whether or not simultaneously with parts of the underlying light-transmitting layer, or
- the local removal of the light-transmitting layer, or
- the local application of one of the component layers.

More in particular, the spaces thus formed are filled partially or entirely with a material exhibiting a different degree of activability than the removed material or the locally applied material.

In another embodiment, said spaces are filled entirely or partially with a liquid or a gas, whose composition determines the refractive index profile of the segments containing said liquid or said gas. This embodiment is especially suitable for measuring the composition of a liquid or a gas mixture or for determining the concentration of the substances which are dissolved in

said liquid.

The local removal of the inclusion material can be realised mechanically, e.g. by stamping in the second inclusion layer, and in particular also by means of photolithography and etching after the application of the second inclusion layer. Thus, a large number, for example hundreds of successive segments can be realised on a relatively short waveguide, for example a waveguide having a length dimension of one mm to a few mm. The above also applies if there are more than two mutually different types of segments.

Such segments may have unequal dimensions and/or be spaced unequal distances apart. The positioning and dimensions of different types of segments can be selected at random, therefore, so that an extra degree of freedom is obtained.

It should be noted that WO 8908273 discloses an optical sensor structure wherein an optical fibre core or another lightguide is covered with an interrupted cladding layer, in such a manner that a transition between water and ice in the cladding causes the sensor operation to switch from wave guidance, that is, functioning as a light-transmitting element, to non-guidance, or vice versa. Thus it is possible to detect the presence or absence of a chemical substance, or in this case water or ice, by means of such a transition.

Another preferred embodiment of the invention is built up of two types of segments, one of which is activable, whilst the other is not. The two types of segments differ from each other as regards the nature of the inclusion material or the light-transmitting material. In one type of segment said material is activable and in the other it is not; the latter material is the so-

called bridge material. In this embodiment the refractive indices of the bridge material and the sensor material are geared to each other with a view to achieving an optimum sensitivity of the activable element for variation of the activating quantity within a particular range. Said gearing to each other implies that a value of the activating quantity exists within said particular range, with the corresponding value of the refractive index of the activable material being equal to that of the inclusion material or the light-transmitting material. This point is called the working point of the activable element.

The bridge material for an activable element by means of which the relative humidity can be measured may for example consist of SiON having a refractive index of for example 1.50, and of a material which is sensitive to air humidity, for example gelatin, having a refractive index range of 1.53 - 1.47 in the air humidity range of 0 - 100%. By increasing the number of segments it is possible, using the same materials, to obtain an extremely steep sensitivity to air humidity, to be defined as a peak-like sensitivity, over a smaller part of the refractive index range to be measured around the air humidity value which corresponds with a gelatin refractive index of 1.50. By increasing the number of segments, said peak effect can even be enhanced. Such a peak-like response can be used as a switching pulse in an electronic circuit composed for that purpose. This method, wherein the number of segments is selected so that a change of a quantity to be measured will result in a peak-like response, can also be used for other sensor applications. Such a sensor is in particular useful for measuring the composition of a liquid or a gas mixture, for example, for the purpose of checking chemical processes or for use in alarm systems to signal the exceeding of humidity limits or the occurrence of

inadmissible air or water pollution. The selection of a refractive index of 1.53 for the bridge material makes it possible to measure refractive index values in the range of 1.52 - 1.53 with great sensitivity, for example. This range corresponds with an air humidity range of 90 - 100%.

In another preferred embodiment, the activable element consists of a light-transmitting material, for example a ridge-type light-transmitting channel, which possesses a constant cross-sectional dimension, and the inclusion layer alternately consists of an activable and an at least substantially non-activable material over the entire width of the mode profile which relevant for the light transmission in the direction of propagation of the light, by which the segments of the activable element are defined.

In another preferred embodiment, the activable material consists of a light-transmitting channel, for example a ridge-type light-transmitting channel, wherein the two types of segments differ from each other as regards the channel width. The two widths are geared to each other in such a manner that when only one type of activable inclusion material is used as a cladding material, the mode field profiles in both types of segments are at least substantially identical for a relevant value of the activating quantity. When the value of the activating quantity changes, the mode field profiles will change in the opposite sense, that is, the mode field profile of one type of segment will become wider, the mode profile of the other type of segment, on the other hand, will become narrower, resulting in a mode field profile mismatch as described before, as a result of which the amount of light transmitted as guided modes on a boundary surface between segments of different types will change, as will the amount of light converted

into radiating modes on said boundary surface and the amount of reflected light.

In another preferred embodiment of a sensor, a reference channel, for example for temperature correction, is incorporated in the device in addition to an activable element of a channel-type lightguide. By using the reference channel as a dummy, which will not come into contact with the medium to be measured, therefore, a reference signal is obtained, which makes it possible to carry out absolute measurements.

In another preferred embodiment, the activable segments are formed by local physical and/or chemical treatment of the inclusion material and/or the light-transmitting material. Thus, an activable inclusion material can be deactivated partially or entirely by means of electromagnetic radiation, for example by UV irradiation, as a result of which the irradiated segments have become non-activable or less activable, contrary to the non-irradiated segments, or react differently, at least in dependence on the refractive index thereof, to such a degree that a usable signal change can be obtained.

In another preferred embodiment, the light-transmitting channel is defined as a strip-loaded (provided with a strip) type of light-transmitting channel within the activable element by applying to said light-transmitting layer a layer of an activable material having a constant thickness of for example 1 - 200 nm, and subsequently removing said material, using suitable techniques, outside the area to be defined as a channel. Alternatively, the strip-loaded type light-transmitting channel can be formed by applying the activable inclusion layer only at the location of the channel area by means of local chemical or physical treatment either

of the area to be defined as the channel area or of the area that does not form part of the channel area. Subsequently, the activable segments and the segments that are not activable or less activable are defined by local treatment of the inclusion material. As a result of this local treatment, the refractive index will hardly vary, if at all, at least at a particular wavelength, as a result of which the refractive index profiles of the two types will be substantially or completely identical at a zero value of the activating quantity, and a maximum transmission of the guided mode will be obtained.

In another preferred embodiment of such a channel-type activable element, for example a strip-loaded or ridge-type element, the activable inclusion material is a chemico-optical material, which can be used for concentration determination in biological tests, in particular pregnancy tests. Activable and less activable segments are defined by local treatment in this activable material, for example by local deactivation by means of local electromagnetic radiation, for example with UV light.

In another preferred embodiment, the light-transmitting layer is homogeneously coated with an activable layer having a thickness of e.g. approximately 1 - 200 nm. This activable layer is subjected to local chemical or physical treatment, as a result of which the degree of activation as well as the refractive index will change. The change in the refractive index of the activable layer is used for the definition of a strip-loaded type of segmented light transmission channel.

Since the differences in the refractive indices of the various types of segments will usually be small in the presence of the activating chemical entities, a

relatively large number of segments will be required. In order to realise this, it is possible to use holographic and Moiré lighting techniques in addition to using patterning by means of masks. Although the periodicity of the structures formed thereby is not required for most uses, this method is especially suitable for those devices according to the invention wherein a fine structure (length dimensions of the segments of for example less than 3 micron) is desired, or wherein specific requirements apply, for example as regards the gradients in the transitions between various materials of activable and non-activable segments.

In one preferred embodiment, the activable segments contain an electro-optical, thermo-optical, magneto-optical, opto-optical or elasto-optical material, as a result of which the transmission of the lightguide device can be controlled by variation of, respectively, the supplied electrical field, the temperature, the magnetic field or the mechanical stress or pressure in the material, thus forming an intensity modulator. In an alternative embodiment of said modulator, one of the layers forming the lightguide consists entirely of an activable material, but the lightguide is only activated locally. Local activation of for example electro-optical and thermo-optical actuators, for example, can take place by applying an electrical tension to locally provided electrodes. The parts provided with electrodes will form the activable segments in that case. In the case of excitation by means of said electrical tension, an electrical field or heating is effected at the location of said activable segments.

In one preferred embodiment, the activators make use of electrodes which have been provided on the activable segments by means of vaporisation, for example, or a similar technique. An electrical field can be applied by

means of such electrodes over a suitable medium whose refractive index can be varied with an electrical field, such as ZnO, as a result of which the guided light beam can be controlled via refractive index profile variation, which in this case means that it is possible to manipulate the intensity thereof. The electrode on the activable element can also be use as a current supply wire for generating heat, as a result of which the reflective index profile will change when suitable materials are used in the activable element, which makes it possible to control the guided light beam locally by means of refractive index profile variation. Besides the aforesaid materials and physical phenomena, also other materials and physical phenomena may be used for intensity modulators if it is possible to generate a refractive index variation therein by means of external activators (whether or not by means of electrodes provided on the activable segments) and/or by means of external influencing, electrically, magnetically, temperature, movement, force, distance, deflection, tension, pressure and the like.

In another preferred embodiment, said activable material consists of a light-transmission channel, for example a ridge-type light-transmission channel, wherein the two types of segments differ from each other as regards the channel width. Said two widths are geared to each other in such a manner that the mode field profiles in the two types of segments are at least substantially identical for a relevant value of the activating quantity. In this embodiment, the second inclusion layer and/or the light-transmitting layer are made up of only one activable material, wherein a non-patterned metal film functions as an electrode. When the value of the activating quantity changes, the mode field profiles will change in the opposite sense, that is, the mode field profile of one type of segment will become wider, the mode profile

of the other type of segment, on the other hand, will become narrower, resulting in a mode field profile mismatch as described before, as a result of which the amount of light transmitted as guided modes on a boundary surface between segments of different types will change, as will the amount of light converted into radiating modes on said boundary surface and the amount of reflected light.

In another preferred embodiment, the activable element consists of two types of segments, which can be activated by different quantities. Thus, one type of segment may contain a chemico-optical material, and the other type of segment may contain an electro-optical material, for example. Said types of segments have at least substantially the same cross-sectional dimension, whilst also the values of the respective refractive indices are geared to each other in such a manner that the refractive index profiles of the two segments are identical for a set of relevant values for each of the activating quantities. At this point, to be called the working point, the transmission factor of the activable element ix maximally T_{max}. In the case of a refractive index change induced by a quantity A, the other type of segment can be forced to undergo an identical refractive index change by means of a properly controllable value of activating quantity B, wherein the identicalness criterion is that the transmission factor be equal to T_{max}. Thus, the value of the quantity A to be measured can be correlated unequivocally with the known value of quantity B. This process can be automated by means of a feedback loop.

In another preferred embodiment, the refractive index profile and/or the material profile at the location of non-activable segments can be optimized for wavelength-sensitive measurements, such that the amount of light

being transported through the device in guided modes is wavelength-dependent, as is the intensity distribution of the light emitted by the segments. Thus it is possible to realise a lightguide device in the form of a spectrometer. In such a spectrometer, an array of photosensitive segments, for example in the form of a photodiode array or a linear CCD chip, is added for measuring laterally emitted light, as a result of which a wavelength-sensitive measurement is realised by means of a location-dependent measurement, viz. in the propagation direction of the lightguide. To that end, the photodiode array contains a number of photodiodes in the propagation direction of the lightguide, and the CCD chip contains a number of elements by which the exiting light can be measured as a function of the propagation direction, thus making it possible to determine a diffusion distribution. The light detector may extend along the entire waveguide length or overlap only part thereof. A light detector array may be provided on one side or on both sides of the lightguide. Both the number of photodiodes of the array and the number of activable segments contribute to the wavelength-dissolving capacity in the diffusion direction.

In another preferred embodiment, activable segments are used, and that exclusively in transmission. No disturbance occurs in quiescent condition thereby. The electrodes are not excited in that case. As soon excitation does take place, a disturbance will occur at each segment, due to a change in the refractive index profile. Said change is not a permanent change, therefore. Each situation, that is, each excitation voltage or current is associated with a particular value of each refractive index profile disturbance. Said resulting refractive index profile disturbance is now perceived differently for each wavelength, because the waveguide exhibits wavelength dispersion. Each

wavelength that is present will pass through the system to a different degree and thus have a different transmission value, therefore. The amount of light that passes through the lightguide has become wavelength-dependent, therefore.

In this situation, that is, upon activation by means of an excitation voltage or current, the total transmission is measured. Then said excitation voltage or current is increased, and the total intensity of the transmission light is measured anew. This is repeated several times in succession, that is, electrode voltages or currents having different values are used each time, and with each of said values a measurement is made of the amount of light exits from the entire system, whereby it is not known at that moment what wavelengths said light contains. On the basis of the amount of light determined by transmission measurement the spectral content of the presented light can be determined afterwards, after such a complete series of measurements has been made, using arithmetic algorithms. Subsequently, the activator is turned off again and all the light will pass through the total system, so that it will be freely available again.

Hereafter a few examples of a device according to the invention will be described in more detail with reference to the drawing. In the drawing:

Figure 1 shows a principle sketch of a device according to the invention;
Figure 2 shows an example of such a device, which is fitted with light supply and discharge means;
Figure 3 shows embodiments of a device comprising a reference channel;
Figure 4 shows different embodiments of activable segments of such a device;
Figure 5 shows an example of a device comprising an

integrated light source and detector;

Figure 6 shows examples of a device in the form of, respectively, a controllable intensity modulator and a spectrometer;

Figure 7 shows an example of a device which can be used as a spectrometer;

Figure 8 shows an example of a device wherein two kinds of activable segments operating on the different widths principle can be used;

Figure 9 is a general representation of a ridge-type channel-type lightguide and a strip-loaded channel-type lightguide; and

Figure 10 is a representation of a segmented strip-loaded lightguide.

A device according to the invention as depicted in Figure 1 comprises a carrier 1, a first inclusion layer 2, a light-transmitting layer 4 and a second inclusion layer 6. Present in inclusion layer 6 are activable segments, in this case in the form of recesses 8 in the inclusion layer, which may extend into the light-transmitting layer for different uses. When the device is used as a sensor, for example for air humidity measurements, measurements of the composition of gases or liquids and the like, said recesses are filled with a medium 17 having a refractive index which is sensitive to the quantity to be measured. Thus it is possible to use gelatin, polyimide etc. for air humidity measurements. In order to realise a sensitive measurement, it is possible to gear refractive index profiles optimally to each other at the location of bridge material 15 and sensor material 17. It is also possible to measure with direct refractive index variations for various measurements, that is, the medium to be measured, for example a gas or a liquid, fills the recesses during the measurement and determines the refractive index thereof, which refractive index

determines the quantity to be measured, for example the concentration of a particular substance therein, or a particular proportion in a mixture of various liquids. An encircled portion 5 of the lightguide structure is shown on a larger scale in the same figure.

The drawing indicates in one of the recesses 8 a measure of the light intensity 10 entering in guided mode for a transition 12, for an intensity 14 reflected at said transition and of the intensity 16 transmitted in guided mode. Arrows 18 indicate that part of the incoming light beam is converted into radiating modes, which will (eventually) exit laterally. It is possible to measure the light exiting in a propagation direction 20 of the lightguide device and/or the light being emitted laterally.

It is furthermore noted that the recesses do not need to be identical or be evenly distributed. Nor is the operation of the device affected if one or more recesses continue deeper or less deeply into the light-transmitting layer or locally enclose said layer completely.

Figure 2 shows an integrated optical channel-type lightguide device, with recesses 8 being provided in inclusion layer 6 again, which recesses are filled with sensor material 17. A light entry fibre 26 is provided on an entry side 24 and a light detection fibre 30 is provided on an exit side 28. A device as described has a length of e.g. one centimetre and a width of a few millimetres, and the number of recesses it contains may range from just a few to a few hundred, depending on the application. Also other channel structures may similarly comprise a light entry fibre and/or a light detection fibre.

Devices as depicted in Figure 3 comprise one or more lateral channels which can be used as reference channels. This makes it possible to compensate external influences, such as the ambient temperature, partially or completely during the measurement and to realise absolute measurements. Figure 3A shows a reference channel 30 which does not pass any activable segments 32 and which is not influenced by the medium to be measured, therefore. Figure 3B shows an embodiment comprising a cuvette 34, which divides the guide into a measuring cuvette 36, which is activated, and a reference cuvette 38, which is not activated, even though it is provided with recesses for activable segments.

Figure 4 shows various embodiments of recesses for activable segments according to the invention, such as a rectangular shape 40, a conical shape 42 and a parallelogram shape 44. The free selection of said shapes provides additional freedom in the selection of sensors or actuators. Especially the degree of laterally emitted light can be varied with the geometry of the transitions. Furthermore, the recesses may be provided perpendicularly to the propagation direction of the guided light beam or at an angle deviating from 90° thereto, or have a different geometry.

It is noted that instead of being formed by recesses, segments may also be formed by a locally deviating physical or chemical treatment of an inclusion layer. Also in that case it is possible to provide the indicated different geometries. This can be realised without having to remove inclusion layer material, therefore.

A device as depicted in Figure 5 comprises an integrated light source 50, an integrated light detector 52 and

open, activable segments 7 as well as segments 9 which are for example provided with an electrode. In this case, such a light source can be selected on the basis of the price, the capacity and the possibility of integration, since the selection of the light source is not bound by specific emission bandwidth requirements to be made thereof, as long as no phase information of the guided light beam is measured. Quite advantageous is for example the use of an LED or a VCSEL light source. The two kinds of segments 7 and 9 may also be positioned in adjoining relationship, to which end the depicted device provides a feedback possibility. Thus it is possible to realise mutual influencing of the signals occurring on both segments, as a result of which it is possible to carry out the aforesaid maximum transmission method.

Two embodiments of an integrated optical lightguide device for use as an intensity modulator are shown in Figures 6a (in side view) and Figure 6B (in plan view). External control of the device as shown in Figure 6a is provided by activable segments 62, which comprise a lower electrode 61, which is required for electro-optical activation, and upper electrodes 60. The refractive index of the sensor material present under the electrodes is varied by means of electric control signals on said electrodes, as a result of which the prevailing refractive index profile at that location is changed and the degree of light transmission is controlled. It is noted that the actuator as shown in Figure 6b may also be configured so that the activable segments are formed by providing electrodes 66 on either side of the channel, as a result of which the refractive index of the material 68 between said electrodes will vary. As the figure schematically indicates, the device comprises a light source 64 and a light detector 65, in this case in the form of a photodiode.

The embodiments which are shown in Figures 6a and 6b can also be used as a spectrometer. In the non-activated condition of the electrodes 60, 66, incident light will pass the device substantially unimpeded. In the activated condition of the electrodes, wavelength-dependent light diffusion will occur, and a reduced amount of light will be emitted, therefore. By measuring the amount of emitted light by means of detector 65 in dependence on the degree of activation of the electrodes, the spectral distribution of the incident light can be calculated afterwards. The spectrally dissolving capacity of the device thereby depends on the number of segments, the sensitivity to dispersion of the transition between two neighbouring segments and the number of selected values of the activating quantity.

Figure 7 shows an embodiment of a spectrometer which cannot be electrically activated. Besides the known parts, this embodiment contains one or two light detector systems 70, for example in the form of a photodiode array or a (linear) chip comprising a linear array of photosensitive elements.

Laterally emitted light 18 from an entering light wave 10 is measured in a locally sensitive manner by means of said detectors. Thus a light diffusion curve and thus the spectral distribution of the exiting light is determined on-line.

Figure 8 is a schematic representation of the embodiment of segments 8 and 8' exhibiting a varying width, seen in plan view A as well as in longitudinal sectional views B and C. The field profiles of the two kinds of segments are substantially the same in this embodiment, but the two types of segments exhibit different refractive index profiles. The illustrated embodiment is an embodiment which comprises an electrode 102, by means of which

intensity modulation and/or spectrometer applications can be realised. The embodiment as shown can also be used for sensor applications, however. No upper electrode 102 is present in that case, and an inclusion layer 100 consists of a sensor material. The illustrated longitudinal sections B and C are sectional views along lines 96 and 98, respectively. The widths of the illustrated segments 8 and 8' are geared to each other in such a manner that when a cladding of inclusion material 100 is present and a significant value of an activating quantity is applied, for example by means of electrode 102, the mode profiles will be at least substantially identical in both types of segments and will vary in opposite sense upon variation of said quantity. In this manner a highly sensitive device is realised.

Figure 9 shows two cross-sectional views of channel-type lightguides, a ridge-type channel lightguide (A) and a strip-loaded type channel lightguide (B), respectively. The ridge of a ridge-type channel lightguide (A) is formed by a local thickening 106 in the light-transmitting material 4. In a strip-loaded type channel lightguide (B), no light-transmitting material is present in outside channel 108. Both embodiments comprise a second inclusion layer 100.

Figure 10 shows by way of illustration a plan view A, a side view B and a cross-sectional view C of a segmented strip-loaded type channel lightguide which does not comprise a second inclusion layer 100. Such a device alternately contains activated segments 110 and non-activated segments 112, which together provide the channel-type light transmission.